JC17 Rec'd PCT/PTO SEP 2 6 2001
US 09/937547

FORM PTO-1390
U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

EXPRESS MAIL LABEL NO.: EL 697 493 395 US

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US)

CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: HPBC Case 83 U.S. APPLICATION NO.

(If known, see 37 CFR 1.5): Unknown

INTERNATIONAL APPLICATION NO.: PCT/EP00/05262 INTERNATIONAL FILING DATE: June 7, 2000

PRIORITY DATE CLAIMED: June 8, 1999

TITLE OF INVENTION: ANALYSIS APPARATUS

APPLICANT(S) FOR DO/EO/US: Joachim WIECHERS, Rainer RIESENBERG and Eckard KOPATZKI

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. [X] This express request to begin national examination procedures (35 U.S.C. 371(f) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(l).
4. [X] A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. [ ] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [ ] is transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] has been transmitted by the International Bureau.
   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US).
6. [X] A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. [ ] Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
   a. [ ] are transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] have been transmitted by the International Bureau.
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [ ] have not been made and will not be made.
8. [ ] A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. [X] An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. [ ] A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

[X] **THE UNDERSIGNED ATTORNEY OF RECORD STATES THAT SMALL ENTITY STATUS IS BEING CLAIMED. 37 CFR §1.27(c)(2) as amended 65 Fed. Reg. 54603, dated September 8, 2000.**

Items 11. to 16. below concern document(s) or information included:

11. [X] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. [X] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. [X] A FIRST preliminary amendment.
    [X] An Amendment Before First Office Action
14. [ ] A substitute specification.
15. [ ] A change of power of attorney and/or address letter.
16. [X] Other items or information:
    1. Drawings (3 sheets)
    2. Copy of WO 00/75640 A1
    3. Acknowledgement Postal Card

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US 09/937547

FORM PTO-1390 U.S. APPLICATION NO. (if know, see 37 CFR 1.5):	INTERNATIONAL APPLICATION NO.:	ATTORNEY'S DOCKET NUMBER:
Unknown	PCT/EP00/05262	HPBC Case 83

17. [X] The following fees are submitted: **CALCULATIONS** PTO USE ONLY

BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5)):

Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO $1000.00

International preliminary examination fee (37CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO .... $ 860.00

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO .... $ 710.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) .... $ 670.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4).... $ 100.00

ENTER APPROPRIATE BASIC FEE AMOUNT = $ 860.00

Surcharge of $130.00 for furnishing the oath or declaration later than [] 20 [] 30 months from the earliest claimed priority date (37 CFR 1.492(e)). $

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	
Total claims	9 - 20 =	0	X $ 18.00	$ 0.00
Ind. claims	1 - 3 =	0	X $ 80.00	$ 0.00
MULTIPLE DEPENDENT CLAIMS (if applicable)			+ $270.00	$ 0.00
TOTAL OF ABOVE CALCULATIONS			=	$ 860.00

Reduction of 1/2 for filing by small entity, if applicable. Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28). - $ 430.00

SUBTOTAL = $ 430.00

Processing fee of $130.00 for furnishing the English translation later than [] 20 [] 30 months from the earliest claimed priority date (37 CFR 1.492(f)). + $

TOTAL NATIONAL FEE = $ 430.00

Fee for recording assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property + $ 40.00

TOTAL FEES ENCLOSED = $ 470.00

Amount to be refunded $

charged $

a. [X] A check in the amount of $470.00 to cover the above fees is enclosed.
b. [ ] Please charge my Deposit Account No. ____________ in the amount of $ ____________ to cover the above fees. A duplicate copy of this sheet is enclosed.
c. [X] The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 06-1382. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

IN DUPLICATE

David S. Goldenberg
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09/937547
JC16 Rec'd PCT/PTO SEP 2 6 2001

PATENT APPLICATION

Express Mail Label No.: EL 697 493 395 US

IN THE U.S. PATENT AND TRADEMARK OFFICE
September 26, 2001

Applicant(s) : Joachim WIECHERS, et al
For : ANALYSIS APPARATUS
PCT International Application No.: PCT/EP00/05262
PCT International Filing Date: June 7, 2000
U.S. Application No.
(if known, see 37 CFR 1.5): Unknown
Atty. Docket No.: HPBC Case 83
Box PCT
Assistant Commissioner for Patents
Washington, DC 20231

PRELIMINARY AMENDMENT CANCELING CLAIMS

Sir:

Prior to calculation of the filing fee in the above-identified application, kindly enter the following:

IN THE CLAIMS

The Applicant cancels Claims 2-9, without prejudice.

REMARKS

This amendment cancels claims 2-9 to reduce the filing fee. Please enter this amendment before calculating the filing fee.

Respectfully submitted,

David S. Goldenberg

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Encl: None
336.9804

09/937547
JC16 Rec'd PCT/PTO SEP 26 2001

PATENT APPLICATION

Express Mail Label No.: EL 697 493 395 US

IN THE U.S. PATENT AND TRADEMARK OFFICE

September 26, 2001

Applicant(s) : Joachim WIECHERS, et al
For : ANALYSIS APPARATUS

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09937547.092601

AMENDMENT BEFORE FIRST OFFICE ACTION

Sir:

Prior to any substantive review of this application, the Applicants make the below stated amendments.

IN THE SPECIFICATION

The Applicants amend page 4 as indicated on the attached marked-up versions of Pages 4 and 4a.

Pursuant to 37 CFR §1.121, attached hereto are Replacement Pages 4 and 4a with the proposed changes properly entered thereon.

IN THE CLAIMS

The Applicants cancel Claim 1, without prejudice.

The Applicants add New Claims 10-18, attached hereto on Replacement Claim pages.

REMARKS

This paper is submitted prior to the issuance of any first substantive Office Action for this application. Entry

of this paper before substantive review of this application is respectfully requested.

At this time the Applicants amend the specification and claims of this application to enter into the application the amendments made during the review of the underlying PCT application.

The Specification was amended to discuss two prior art documents. The entry of this material does not add new matter to this application.

Claim 1 has been cancelled and New Claims 10-18 added therefore. Claim 10 is the sole independent claim. Claims 11-18 are dependent from Claim 10. Claims 10-18 are English language, United States claim drafting style versions of Claims 1-9 that were reviewed and the subject of the International Preliminary Examination Report for this application. It is noted that the EPO, in its capacity as the International Preliminary Examining Authority for this application found that these claims are all directed to an invention that is both novel and the result of an inventive step over the prior art.

Respectfully submitted,

David S. Goldenberg

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Encl:
Marked-up Amended Specification pages 4 and 4a
Replacement Specification pages 4 and 4a
Replacement Claims

336.9804

the course of time through attack by aggressive media. More-over, exact adjustment of the mirrors and thus an elaborate adjusting device is necessary. Also, the adjustable mirrors form gaps and similar cavities which delay the exchange of the substance to be measured and thus lead to memory effects.

According to EP 0 780 681 A2, the reference beam traverses a reference cell filled with reference gas, but this involves the above-described disadvantages of prismatic beam splitting. Furthermore, it does not permit changes in the optical properties of the measuring cell to be detected. The miniaturization of such assemblies is limited.

Alternatively, measuring and reference beams are both guided through the measuring cell but measured in different wave ranges. The reference beam is either measured in such broadband fashion that the intensity change through extinction at the characteristic wavelengths of the substance to be measured is irrelevant, or it is measured in narrow-fashion band like the measuring beam but at another wavelength. The disadvantage of the first method is that a change in spectral distribution of the radiation source due to temperature fluctuations or signs of aging will generally influence measuring and reference signals differently. The disadvantage of the second method is the uncertainty about the nonoccurrence of absorption at the reference wavelength due to unknown substances. This is dangerous specifically in the case of abient air monitoring for toxic gases since absorption at the reference wavelength

leads to a reduction of sensitivity in the measuring path.

According to US 4,281,248 the radiation of an IR radiation source is supplied to optopneumatic detectors with a chopper alternatively via a reference radiation path and a measuring radiation path. The gas to be measured flows through a long cell in the measuring radiation path and then through a short cell in the reference radiation path.

According to US 5,876,674 the radiation of a radiation source is split into two radiation paths and the gas to be measured guided through an absorption chamber having in each radiation path two optical elements formed as aligned glass rods each at different distance so that the optical path length in the absorption chamber is greater between one pair of optical elements than with the other pair.

The invention is based on the problem of providing an analyzer for determining concentration by transmission measurement which is compact and stable toward outside mechanical and thermal influences and permits a wide concentration range - from a few ppm to several ten percent - to be determined reliably and continuously.

the course of time through attack by aggressive media. More-over, exact adjustment of the mirrors and thus an elaborate adjusting device is necessary. Also, the adjustable mirrors form gaps and similar cavities which delay the exchange of the substance to be measured and thus lead to memory effects.

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The invention is based on the problem of providing an analyzer for determining concentration by transmission measurement which is compact and stable toward outside mechanical and thermal influences and permits a wide concentration range - from a few ppm to several ten percent - to be determined reliably and continuously.

10. (New) A device for determining the concentration of one or more substances in a mixture by measuring the concentration-dependent molecule-specific extinction of radiation, comprising:

an absorption chamber filled with the sample to be measured;

a radiation source;

two, or a number divisible by two of, receivers, one pair of receivers being associated with the measurement of the concentration of each component of the mixture;

a device for splitting the radiation from the radiation source into two, or a number divisible by two of, radiation paths to the receivers, all radiation paths from the radiation source to the receivers traversing the same number and pairwise identical optical elements and the substance in the absorption chamber, and the two radiation paths leading to a pair of receivers each having a different optical length in the absorption chamber;

a device for measuring the extinction in the two radiation paths leading to a pair of receivers at the same wavelength; and

a device for determining the measured value or values by comparison of the intensities measured by the receivers of a pair, wherein

for splitting the radiation from the radiation source, two concave mirrors associated with a pair of receivers are provided which focus the radiation arriving from the radiation source onto the receivers, said two concave mirrors associated with a pair of receivers being disposed at different distances from the radiation source

to form radiation paths of different lengths in the absorption chamber.

11. (New) The device of Claim 10, wherein at least one of said two concave mirrors associated with a pair of receivers is formed as an aspheric concave mirror.

12. (New) The device of Claim 10, wherein said aspheric concave mirror constitutes a section of a spheroid.

13. (New) The device of Claim 10, wherein the radiation source is an electrically modulable plane radiator.

14. (New) The device of Claim 10, wherein the absorption chamber is formed by an interior of a housing and said concave mirrors are formed integrally with the housing.

15. (New) The device of Claim 14, wherein said housing is of partite form and said concave mirrors are formed integrally with a housing part.

16. (New) The device of Claim 15, wherein said housing comprises a first housing part with said concave mirrors and a second housing part on which the radiation source and the receivers are disposed.

17. (New) The device of Claim 16, wherein at least said first housing part with the concave mirrors is made of metal.

18. (New) The device of Claim 16, wherein said first housing part is made from aluminum.

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JC16 Rec'd PCT/PTO SEP 26 2001

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Analysis Apparatus

This invention relates to an analyzer for determining the concentration of one or more substances in a mixture by measuring the concentration-dependent molecule-specific extinction according to the preamble of claim 1.

Nondispersive photometers for determining the concentration of a substance in a mixture are widely known and used for a great variety of measuring tasks. Thus, commercial medical measuring instruments for determining CO_2 content in tidal air, so-called capnometers, are based on this principle. Said devices evaluate the attenuation of introduced infrared radiation at the wavelength of 4.26 microns characteristic of CO_2 according to Lambert-Beer's law

$$I = I_0 \exp[-kCL]$$

where
- I: Detected intensity
- I_0: Irradiated intensity
- k: Specific extinction coefficient
- C: Concentration
- L: Optical path length

as a measure of the CO_2 concentration present in the sample.

In the simplest form, nondispersive photometers work according to a single-beam method (cf. EP 0 794 423 A1).

IR radiation whose intensity is assumed to be constant is passed from a radiation source through the volume penetrated by the sample under testing and measured therebehind for its intensity using an optoelectric detector as a radiation receiver. The selectivity for the substance to be detected is ensured by restricting the IR spectrum to the characteristic wavelength(s) by a narrow-band filter disposed either behind the radiator or in front of the receiver.

Alternatively, unfiltered light is passed behind the absorption chamber in a closed chamber filled with the sub-

stance to be determined, in which chamber the radiant energy of the radiation source attenuated at the characteristic wavelength(s) in accordance with the concentration present in the absorption chamber is converted into thermal energy by optical excitation at exactly the characteristic wavelength(s) and detected as pressure (optopneumatic detector).

In order to obtain the signal-to-noise ratio required for the necessary measuring accuracy, periodic modulation of the signal is imperative. This is classically effected by the use of rotating beam chopping disks, so-called choppers. Since these are mechanically moving parts, this solution has inherent disadvantages with respect to minimum attainable size, interference susceptibility due to the action of external force, and perturbing effects such as vibrations or sound caused by the rotation. In modern devices one therefore uses compact, thermal thin-film or thick-film radiation sources which are operated with clocked current and thus emit periodically modulated radiation themselves.

The single-beam method with one radiation source and one receiver is hardly applied, however, since temperature and intensity fluctuations and aging phenomena of the radiation source, optical elements and receiver lead to strong drift of the output signal. In order to compensate said effects one usually employs a double-beam method which uses a second radiation path not influenced by the substance to be measured as a reference. The signals of the first (measuring) and second (reference) radiation paths are ratioed and the ratio used for determining the concentration.

Double-beam methods by which the radiation from the radiation source is split into measuring and reference radiation paths to two receivers can be realized with optical devices differing in the number of radiation sources, cells and/or receivers. A device with two radiation sources, one cell and two receivers is described e.g. in US 3,734,631.

Compensation of thermal and aging effects in the cell is intrinsic to the method. Moreover, considerable measuring and automatic-control effort is necessary for keeping the radiant power of the two radiation sources constant, for instance by using two additional receivers for measuring the radiant power emitted by the radiation sources before the cell is traversed. A simplification of this assembly in that both radiation paths are passed onto one receiver is described in US 4,899,053. However, no stabilization of the intensities of the two radiation sources is provided.

Intensity fluctuations due to temperature fluctuations or signs of aging of the radiation source can be compensated intrinsically if both radiation paths, i.e. the reference and measuring radiation paths, are operated from the same radiation source. For this purpose one must perform beam splitting which is typically realized by prisms or semitransparent, partially dichroic mirrors in front of or behind the absorption chamber (cf. EP 0 834 732 A2).

However, such optical components reduce intensity, which reduces the signal-to-noise ratio and thus worsens the lower detection limit. Furthermore, the spectral properties of such elements can change in the course of time through deposits or attack by aggressive media, which can lead to a shift of the intensity ratio between measuring and reference paths.

Advantageous beam splitting via imaging mirrors within the sample chamber doing without intensity-attenuating elements is described in DE 44 37 188 C2. The central requirement for the reference path is that its intensity not be influenced, or influenced substantially less than the measuring path, by concentration changes in the substance to be measured. For this purpose the reference path is guided almost completely through a transparent block of calcium fluoride in the interior of which there is no attenuation of light by the substance to be measured. However, such a block can cloud in

the course of time through attack by aggressive media. Moreover, exact adjustment of the mirrors and thus an elaborate adjusting device is necessary. Also, the adjustable mirrors form gaps and similar cavities which delay the exchange of the substance to be measured and thus lead to memory effects.

According to EP 0 780 681 A2, the reference beam traverses a reference cell filled with reference gas, but this involves the above-described disadvantages of prismatic beam splitting. Furthermore, it does not permit changes in the optical properties of the measuring cell to be detected. The miniaturization of such assemblies is limited.

Alternatively, measuring and reference beams are both guided through the measuring cell but measured in different wave ranges. The reference beam is either measured in such broadband fashion that the intensity change through extinction at the characteristic wavelengths of the substance to be measured is irrelevant, or it is measured in narrow-fashion band like the measuring beam but at another wavelength. The disadvantage of the first method is that a change in spectral distribution of the radiation source due to temperature fluctuations or signs of aging will generally influence measuring and reference signals differently. The disadvantage of the second method is the uncertainty about the nonoccurrence of absorption at the reference wavelength due to unknown substances. This is dangerous specifically in the case of ambient air monitoring for toxic gases since absorption at the reference wavelength leads to a reduction of sensitivity in the measuring path.

The invention is based on the problem of providing an analyzer for determining concentration by transmission measurement which is compact and stable toward outside mechanical and thermal influences and permits a wide concentration range - from a few ppm to several ten percent - to be determined reliably and continuously.

This is obtained according to the invention with the analyzer characterized in claim 1. The subclaims state advantageous embodiments of the inventive analyzer.

According to the invention, two radiation paths, i.e. a first radiation path from the radiation source to a first receiver and a second radiation path from the radiation source to a second receiver, traverse the absorption chamber containing the sample with the substance whose concentration is to be determined.

In both radiation paths measuring is done at the same wavelength. However, the two radiation paths have a different length, the first being substantially longer than the second, preferably at least twice, in particular at least four times, as long. This causes the radiation passing along the first, long path to be attenuated accordingly more in the presence of the substance to be detected than the radiation along the second, shorter path.

In delimitation over the prior art, the two radiation paths are thus not only guided completely through the sample to be measured but are furthermore measured at the same wavelength. This results in optical equivalence of the two beams which avoids essential disadvantages of the approaches hitherto described. Due to the equivalent beam control, any intensity-attenuating perturbing effects possibly occurring in the course of time act on both radiation paths to the same extent. Due to the measurement of both radiation paths at the same wavelength, the measuring result is independent of the spectral distribution of the radiation source, the spectral properties of the optical elements or changes thereof through aging effects since both radiation paths are influenced to the same extent here too.

The greatly different absorption paths in the two radiation paths furthermore permit the dynamic range of the device to be advantageously widened. If at high concentrations of

the substance to be measured the absorption in the long radiation path is so strong that the signal arriving at the detector falls below the noise limit, the signal from the shorter radiation path can be evaluated directly. The attainable dynamic gain corresponds to the ratio of the two absorption paths.

From the radiation intensity measured by each receiver one forms an intensity comparative value, for example the quotient of the intensities measured by the first and second receivers, said measured intensity comparative value or intensity quotient corresponding to a certain concentration of the substance to be measured. If one applies Lambert-Beer's law as mentioned above to both radiation paths, forms the quotient of the two equations, takes the logarithm and solves for concentration, one obtains

$$C = -1 /(k L_1 - k L_2) \ln (I_1 / I_2)$$

On the other hand, one can first logarithmize the two equations, expand them accordingly, subtract from each other and solve for irradiated intensity. One obtains

$$I_0 = \exp[L_1 \ln I_2 - L_2 \ln I_1 /(L_1 - L_2]$$

Evaluation of the signals of both receivers thus permits not only the determination of concentration C but also a statement about irradiated power I_0. Even if this value is for technical reasons not used for controlling the radiation source, it can be used for redundant functional testing of the analyzer.

The method can be performed not only in single-channel fashion, i.e. for determining the concentration of a substance in a sample, but also in multi-channel fashion, i.e. for simultaneously determining the concentrations of a plurality of substances in a mixture. In the latter case one requires a pair of radiation paths, a first long one and a sec-

ond short one, for each individual channel to be measured. However, the radiation paths of all channels are operated from the same radiation source and guided through the same sample according to the invention.

The inventive analyzer or photometer is applicable in particular for determining substances in gas mixtures. However, it can also be used to determine the concentration of a substance in a liquid.

Due to the monolithic assembly and the resulting high mechanical stability, the inventive analyzer is compression-proof and also helium-leakproof. It can accordingly be used for measurements in the pressure range from vacuum to 10 bar for example.

As radiation one uses in particular infrared radiation. The infrared radiation source irradiates the sample to be analyzed and the receivers or detectors measure the attenuation of the IR radiation. The selectivity for a certain substance is obtained by narrow-band filtering of the light to a range in which the substance absorbs IR radiation as greatly as possible in a characteristic wave range through molecule vibrations.

As an IR radiation source one preferably uses a thermal IR radiation source; one also preferably uses thermal receivers, e.g. pyrodetectors or thermopiles. However, it is also possible to use alternative electrooptical radiation sources such as diode lasers which work at low temperatures, or gas lasers. As receivers one can also use quantum detectors.

To form the two optical paths of different lengths belonging to a channel in the absorption chamber one preferably provides two mirrors in the absorption chamber which are disposed at different distances from the IR radiation source and reflect radiation of the radiation source onto first and second receivers.

The mirrors are preferably formed according to the invention by concave mirrors, whereby one preferably uses aspheric mirrors, in particular mirrors whose surface is formed by a section of a spheroid. Thus the light emitted by the radiation source is focused almost completely onto the receivers.

As a radiation source one therefore uses according to the invention an IR plane radiator produced by the thin- or thick-film technique. Since plane radiators have an angular distribution of emission following the law of cosines and thus emit a strongly forward directed radiation in contrast to point or line radiators, their radiation can be focused especially advantageously onto the receivers. In order to be protected from aging through gas contact or destruction upon measurement of reactive gases, the radiation source is preferably disposed outside the absorption chamber, i.e. separated gastight by an optical window from the absorption chamber and thus the substance to be measured.

The filter for filtering out the wave range of IR radiation characteristic of the substance to be measured can be disposed on the radiation source or both receivers in the case of single-channel measurement. In the case of multichannel measurement the filters must be mounted in front of the receivers.

If the filters are mounted in front of the receivers, they must have pairwise exactly identical optical properties. In order to avoid differences in optical properties, as occur for production reasons both between different batches of filter material and due to inhomogeneities on one and the same disk of a filter, the filters belonging to a channel are especially advantageously cut out of adjacent areas of one and the same filter disk.

The inventive analyzer preferably has a monolithic assembly. That is, the mirrors are formed integrally with the housing whose interior forms the absorption chamber. For in-

tegral formation with the housing, the mirrors can be produced by machining the inside of the housing, forming the mirrors when casting the housing or the like. One can thus also do without installation of the mirrors and adjustment of the mirrors.

So that the interior of the housing is accessible, the housing is preferably partite. The mirrors are then preferably formed integrally with the same housing part. Due to this monolithic assembly one also requires few seals.

Since the interior of the housing at the same time forms the absorption chamber there are no separating surfaces, dead volumes or mountings between housing and mirrors, absorption chamber and housing, etc., with the monolithic design of the inventive analyzer. One thus obtains not only fast media exchange without memory effects but also reliably maintains the imaging geometry of the inventive device in case of temperature changes or mechanical influences.

The integral formation of the mirrors with the housing or the one housing part on which they are provided results in first-order compensation of thermal expansions upon temperature changes which would lead to a change of the lengths of the two optical paths belonging to a channel relative to each other. At the same time, the integral formation of the mirrors with the housing or the one housing part obtains high mechanical stability and thus effectively prevents a signal change due to outside mechanical influences.

The housing is preferably made of metal. This ensures not only high stiffness and thus high mechanical stability but also fast temperature compensation, in particular through metals high thermal conductivity and low heat capacity in order to ensure a fast temperature balance.

Suitable metals have proved to be in particular aluminum materials, i.e. aluminum metal or aluminum alloys, in particular temper annealed metal or aluminum materials, in order

to prevent slow drift through internal stresses and thereby ensure high long-term stability.

Apart from that, aluminum materials permit the mirrors to be easily worked out for example by machining. Moreover, mirror surfaces of aluminum materials have high IR reflectivity. Mirror surfaces of aluminum materials are also inert to most media or they form a corrosion-inhibiting protective layer, for example toward oxygen (air) or fluorine-containing compounds through an Al_2O_3 or AlF_3 protective layer. This layer is generally so thin that the optical properties are not influenced.

A metal housing moreover ensures an electric and magnetic shielding, which is important in particular for very small signals. The electronic housing receiving the devices for signal processing can be fastened to the photometer housing with the absorption chamber, the radiation source, the two receivers and the two mirrors, thereby ensuring good shielding for the total signal path. The electronic housing is for this purpose preferably made of the same material as the photometer housing, also in order to prevent temperature stresses due to different temperature expansion coefficients.

The radiation of the radiation source is preferably modulated in order to be independent of background radiation on the receiver side. If one wants to do without mechanically moving parts (choppers), the radiation source must be designed so as to be electrically modulated.

The inventive analyzer can be used for example for analyzing environmentally harmful or toxic gas, in particular for continuous monitoring of waste gases, for example for monitoring waste-gas cleaning installations. Environmentally harmful gases which can be analyzed with the inventive device are in particular inert, fluorine-containing gases, for example fluorinated or perfluorinated hydrocarbons, nitrogen trifluoride or sulfur hexafluoride.

With the inventive device one can reliably and continuously determine the concentration of one or more substances of e.g. less than 1 ppm to 50% and more.

In the following a single-channel and a double-channel embodiment of the inventive analyzer will be explained in more detail by way of example with reference to the drawings, in which:

FIG. 1 shows schematically a view of the radiation path of the device;

FIGS. 2a and 2b show perspective views of the two housing half-members of the device in the open state; and

FIGS. 3a and 3b show perspective views of the two housing half-members of the double-channel device in the open state.

The device accordingly has two housing parts 1, 2 of substantially equal size indicated by dashed lines in FIG. 1.

According to FIG. 2, housing half-members 1, 2 are of substantially cuboid form, for example made of an aluminum material. Between housing half-members 1, 2 there is sealing ring 3. Bores 4, 5 are for screwing housing half-members 1, 2 together.

A cavity is worked out of inside 6 of housing half-member 2 to form concave mirror 7. Further, projection 8 is worked out of inside 6 of housing half-member 2, and smaller second concave mirror 9 at the tip of projection 8. First concave mirror 7 is disposed at a substantially greater distance from IR radiation source 11 than second concave mirror 9. Concave mirrors 7, 9 integral with housing part 2 each form sections of a spheroid, the axes of the spheroid of first concave mirror 7 being accordingly greater than the axes of the spheroid of second concave mirror 9. The two spheroids are so disposed that the radiation source and one of the receivers are located at the focal points in each case. Inside 12 of housing part 1 likewise has a cavity for receiving projection 8, among other things.

The cavities on insides 6, 12 of housing parts 2, 1 form absorption chamber 13 of the mounted housing (FIG. 1).

The medium to be analyzed is supplied to absorption chamber 13 via bore 14 in the wall of housing part 2 which is opposite mirror 7 (FIG. 2b). The medium exits through another bore (not shown) in housing part 1 or 2.

IR radiation source 11, formed as a plane radiator, is disposed outside housing part 1 on opening 16. Further, first receiver 17 is provided on opening 18 and second receiver 19 on another opening 21 in housing part 1 (FIG. 2).

According to FIG. 1, radiation from radiation source 11 is split on the edge of mirror 9 facing mirror 7 into radiation paths 22 and 23, preferably and especially advantageously in equal shares. Radiation paths 22, 23 from radiation source 11 to receivers 17, 19 traverse absorption chamber 13 and thus the substance to be analyzed contained therein. The one radiation path 22 by which part of the radiation from the radiation source is reflected by large mirror 7 has a substantially greater length than radiation path 22 with reflection on other mirror 9.

The double-channel configuration shown in FIG. 3a/b differs from the single-channel configuration shown in FIG. 2 a/b only in the number of receivers and the formation of the mirrors. Instead of the single receivers in housing openings 18 and 21 in the single-channel configuration, one inserts two receivers in each case into housing openings 18 and 21, 18a and 21a (FIG. 3a) here. In the double-channel configuration, mirrors 7 and 9 of the single-channel configuration are broken in the plane shown in FIG. 1 and tilted away orthogonally therefrom such that the radiation source in housing opening 16 and the receivers in openings 18 and 21, 18a and 21a are seated at the focal points of mirrors 7 and 9, 7a and 9a in each case (FIG. 3b).

Patent claims

1. A device for determining the concentration of one or more substances in a mixture by measuring the concentration-dependent molecule-specific extinction of radiation, comprising
   - an absorption chamber filled with the sample to be measured,
   - a radiation source, and
   - two, or a number divisible by two of, receivers, one pair of receivers being associated with the measurement of the concentration of each component of the mixture,

   wherein
   - the radiation from the radiation source is split into two, or a number divisible by two of, radiation paths to the receivers,
   - all radiation paths from the radiation source to the receivers traverse the substance in the absorption chamber,
   - all radiation paths from the radiation source to the receivers traverse the same number and pairwise identical optical elements,
   - the two radiation paths leading to a pair of receivers each have a different optical length in the absorption chamber,
   - the extinction in each radiation path leading to a pair of receivers is measured at the same wavelength, and
   - the measured value or values are determined by comparison of the intensities measured by the receivers (17, 19) of a pair,

   characterized in that for splitting the radiation from the radiation source (11) concave mirrors (7, 7a, 9, 9a)

are provided which focus the radiation arriving from the radiation source (11) onto the receivers (17, 19), the two mirrors (7, 7a, 9, 9a) associated with a pair of receivers (17, 19) being disposed at different distances from the radiation source (11) to form radiation paths (22, 23) of different lengths in the absorption chamber (13).

2. A device according to claim 1, characterized in that at least one of the two concave mirrors (7, 7a, 9, 9a) associated with a pair of receivers (17, 19) is formed as an aspheric concave mirror.

3. A device according to claim 2, characterized in that the aspheric concave mirrors (7, 7a, 9, 9a) constitute sections of a spheroid.

4. A device according to any of the above claims, characterized in that the radiation source (11) is an electrically modulable plane radiator.

5. A device according to any of the above claims, characterized in that the absorption chamber (13) is formed by the interior of the housing (1, 2) and the concave mirrors (7, 7a, 9, 9a) are formed integrally with the housing (1, 2).

6. A device according to claim 5, characterized in that the housing (1, 2) is of partite form and the concave mirrors (7, 7a, 9, 9a) are formed integrally with the same housing part (2).

7. A device according to claim 6, characterized in that the radiation source (11) and the receivers (17, 19) are disposed on the other housing part (1).

8. A device according to claim 6 or 7, characterized in that at least the housing part (2) with the concave mirrors (7, 7a, 9, 9a) is made of metal.

9. A device according to claim 8, characterized in that the metal is an aluminum material.

Fig. 1

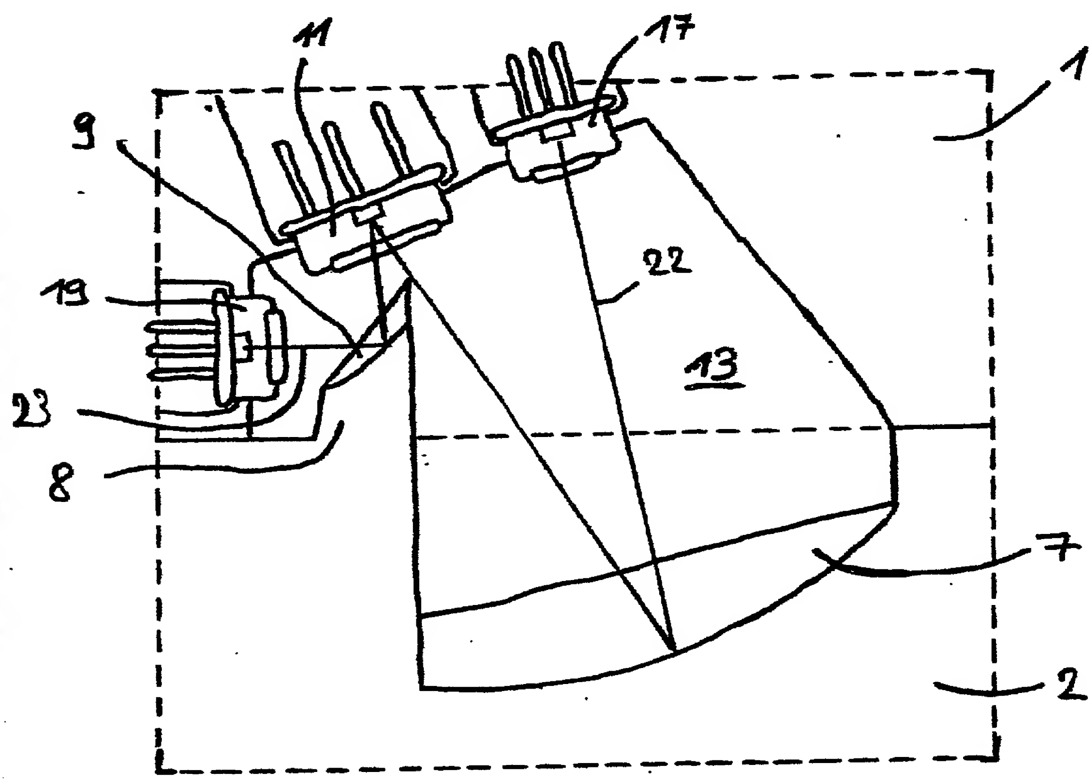


Fig. 2a

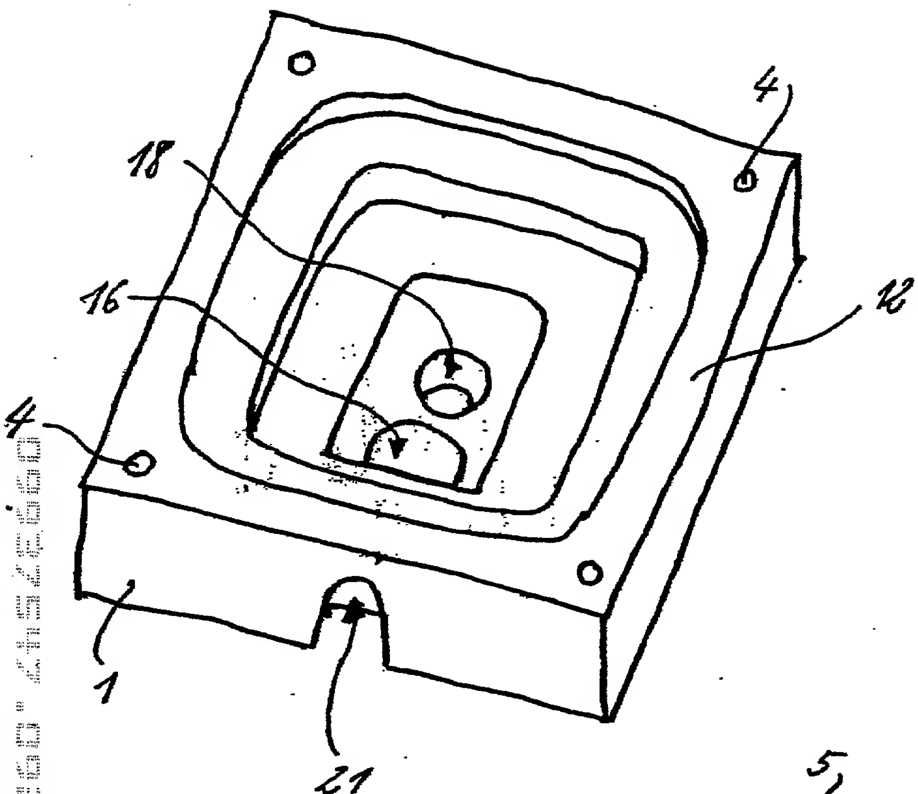
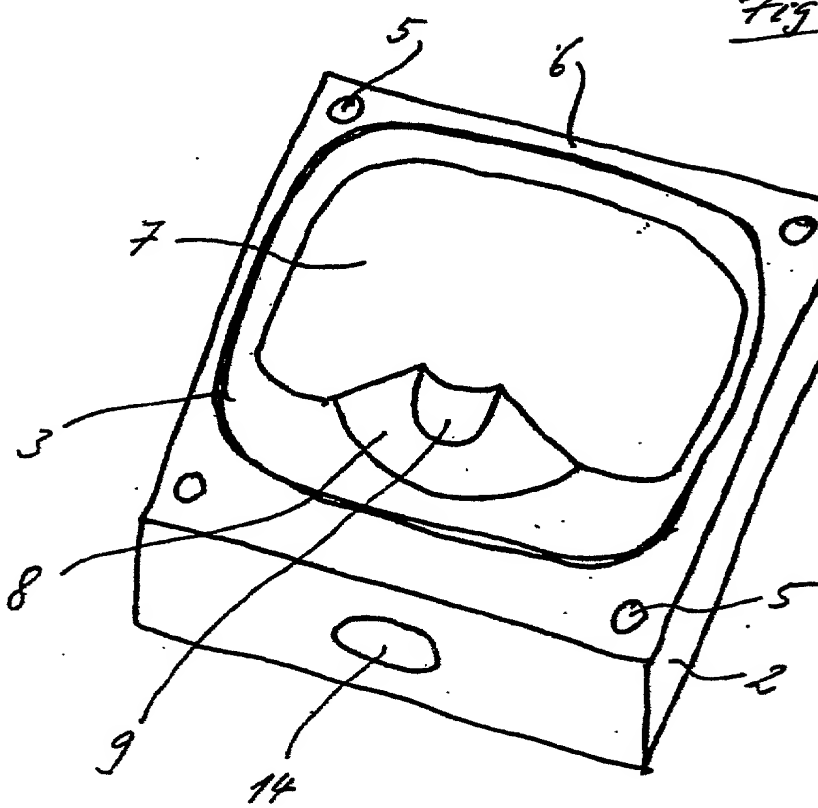


Fig. 2b



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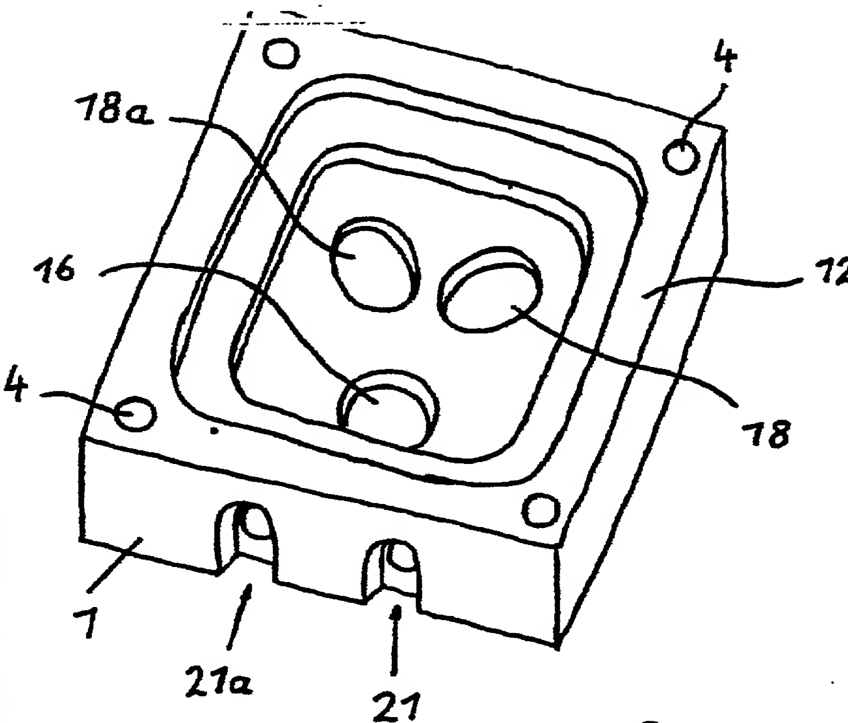

Fig 3a

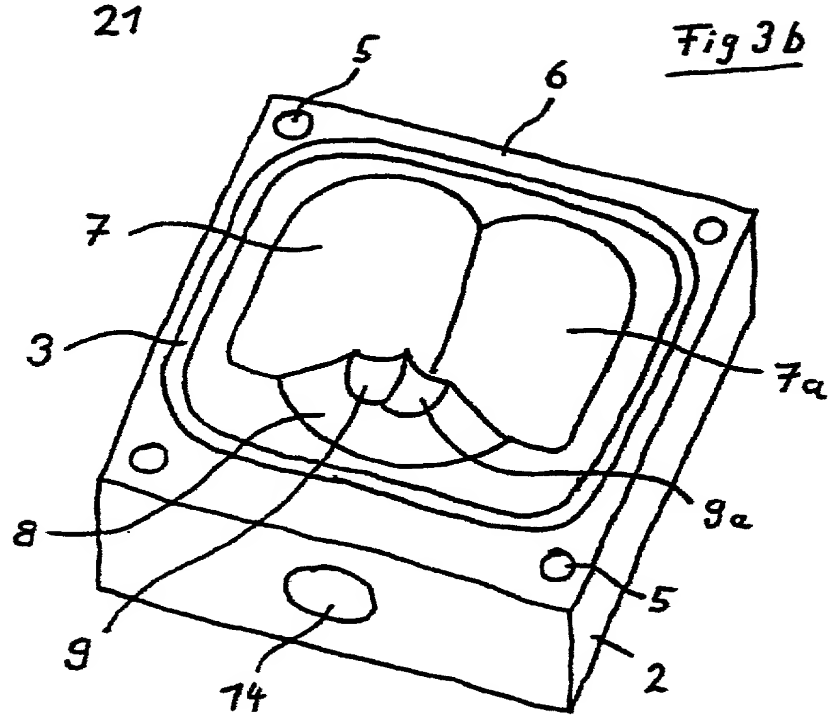

Fig 3b

Declaration and Power of Attorney for Patent Application
Erklärung für Patentanmeldungen mit Vollmacht

German Language Declaration

Als nachstehend benannter Erfinder erkläre ich hiermit an Eides Statt:

daß mein Wohnsitz, meine Postanschrift und meine Staatsangehörigkeit den im nachstehenden nach meinem Namen aufgeführten Angaben entsprechen, daß ich nach bestem Wissen der ursprüngliche, erste und alleinige Erfinder (falls nachstehend nur ein Name angegeben ist) oder ein ursprünglicher, erster und Miterfinder (falls nachstehend mehrere Namen aufgeführt sind) des Gegenstandes bin, für den dieser Antrag gestellt wird und für d... ein Patent für die Erfindung mit folgendem Titel beantragt wird:

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deren Beschreibung hier beigefügt ist, es sei denn (in diesem Falle Zutreffendes bitte ankreuzen), diese Erfindung

☐ wurde angemeldet am ____________
unter der US-Anmeldenummer oder unter der Internationalen Anmeldenummer im Rahmen des Vertrags über die Zusammenarbeit auf dem Gebiet des Patentwesens (PCT)
________________ und am
________________ abgeändert (falls zutreffend).

Ich bestätige hiermit, daß ich den Inhalt der oben angegebenen Patentanmeldung, einschließlich der Ansprüche, die eventuell durch einen oben erwähnten Zusatzantrag abgeändert wurde, durchgesehen und verstanden habe.

Ich erkenne meine Pflicht zur Offenbarung jeglicher Informationen an, die zur Prüfung der Patentfähigkeit in Einklang mit Titel 37, Code of Federal Regulations, § 1.56 von Belang sind.

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

ANALYSIS APPARATUS

____

the specification of which is attached hereto unless the following box is checked:

☒ was filed on June 7, 2000
as United States Application Number or PCT International Application Number
PCT/EP00/05262 and was amended on
________________ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56.

German Language Declaration

Ich beanspruche hiermit ausländische Prioritätsvorteile gemäß Title 35, US-Code, § 119 (a)-(d), bzw. § 365(b) aller unten aufgeführten Auslandsanmeldungen für Patente oder Erfinderurkunden, oder § 365(a) aller PCT internationalen Anmeldungen, welche wenigstens ein Land ausser den Vereinigten Staaten von Amerika benennen, und habe nachstehend durch ankreuzen sämtliche Auslands- anmeldungen für Patente bzw. Erfinderurkunden oder PCT internationale Anmeldungen angegeben, deren Anmeldetag dem der Anmeldung, für welche Priorität beansprucht wird, vorangeht.

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Prior Foreign Applications
(Frühere ausländische Anmeldungen)

Priority Not Claimed
Priorität nicht beansprucht

(Number) (Nummer)	(Country) (Land)	(Day/Month/Year Filed) (Tag/Monat/Jahr der Anmeldung)	Priority Not Claimed
199 26 121.0	Germany	8 June 1999	☐
			☐

Ich beanspruche hiermit Prioritätsvorteile unter Title 35, US-Code, § 119(e) aller US-Hilfsanmeldungen wie unten aufgezählt.

I hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s)listed below.

(Application No.) (Aktenzeichen)	(Filing Date) (Anmeldetag)

Ich beanspruche hiermit die mir unter Title 35, US-Code, § 120 zustehenden Vorteile aller unten aufgeführten US-Patentanmeldungen bzw. § 365(c) aller PCT internationalen Anmeldungen, welche die Vereinigten Staaten von Amerika benennen, und erkenne, insofern der Gegenstand eines jeden früheren Anspruchs dieser Patentanmeldung nicht in einer US-Patentanmeldung, bzw. PCT internationalen Anmeldung in in einer gemäß dem ersten Absatz von Title 35, US-Code, § 112 vorgeschriebenen Art und Weise offenbart wurde, meine Pflicht zur Offenbarung jeglicher Informationen an, die zur Prüfung der Patentfähigkeit in Einklang mit Title 37, Code of Federal Regulations, § 1.56 von Belang sind und die im Zeitraum zwischen dem Anmeldetag der früheren Patentanmeldung und dem nationalen oder im Rahmen des Vertrags über die Zusammenarbeit auf dem Gebiet des Patentwesen (PCT) gültigen internationalen Anmeldetags bekannt geworden sind.

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s), or § 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

(Application No.) (Aktenzeichen)	(Filing Date) (Anmeldetag)	(Status) (patented, pending, abandoned) (Status) (patentiert, schwebend, aufgegeben)

Ich erkläre hiermit, daß alle in der vorliegenden Erklärung von mir gemachten Angaben nach bestem Wissen und Gewissen der Wahrheit entsprechen, und ferner daß ich diese eidesstattliche Erklärung in Kenntnis dessen ablege, daß wissentlich und vorsätzlich falsche Angaben oder dergleichen gemäß § 1001, Title 18 des US-Code strafbar sind und mit Geldstrafe und/oder Gefängnis bestraft werden können und daß derartige wissentlich und vorsätzlich falsche Angaben die Rechtswirksamkeit der vorliegenden Patentanmeldung oder eines aufgrund deren erteilten Patentes gefährden können.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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(Supply similar information and signature for third and subsequent joint inventors.)

[X] Additional inventors are being named on the one supplemental additional inventor(s) sheet.

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Unterschrift des Erfinders Datum	Third signature Date Kopatzki Aug 20th, 2001
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Postanschrift	Post Office Address

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Wohnsitz	Residence
Staatsangehörigkeit	Citizenship
Postanschrift	Post Office Address

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[X]. This Declaration ends with this page.